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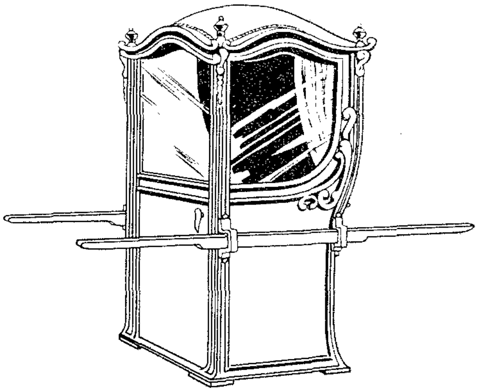

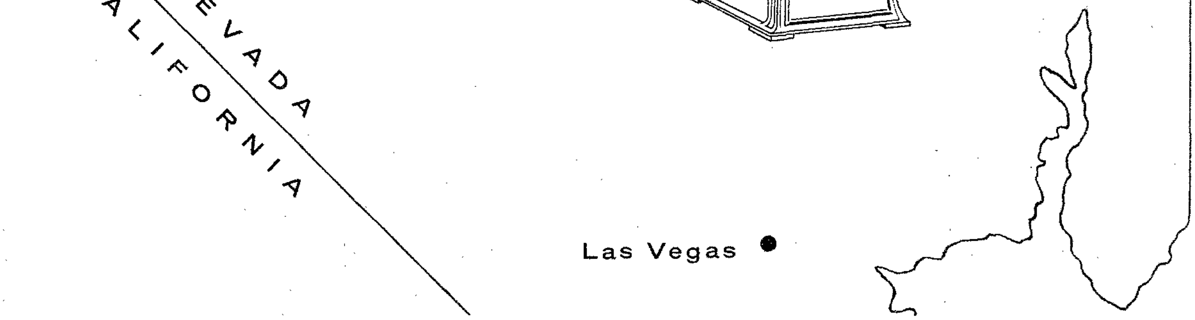

Influence of a Cratering Device on Close-in Populations of Lizards

Frederick B. Turner

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INFLUENCE OF A CRATERING DEVICE ON CLOSE-IN POPULATIONS OF LIZARDS

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December 20, 1962

ABSTRACT

Prior to the Sedan test on July 6, 1962, the density of adult lizards northeast of the prospective ground zero was estimated on the basis of repeated sampling of selected areas. Samples were taken by hand collecting and by means of buried cans, which served as traps for both lizards and various species of arthropods.

Measurements of cumulative gross gamma dosages in the study areas were also made: at 2" and 36" above the ground, 2" below the ground, and in the tissues of lizards by means of small implanted glass micro-dosimeters.

In shrubby areas northeast of ground zero, the pre-test density of Cnemidophorus tigris in June was estimated at 5-10 per acre, the density of Crotaphytus wislizeni at 1-2 per acre. No juveniles of either species were observed. Densities of Uta stansburiana and Phrynosoma platyrhinos could not be estimated from the data acquired.

After the test, during August and again in November, no adult lizards were observed closer to ground zero than 5500 ft. However, adult lizards were only rarely observed in areas which experienced neither blast damage nor lethal levels of gamma radiation. Hence, except, within about 2000 ft of ground zero, the apparent low incidence of adult lizards after the test cannot be ascribed to the detonation. A period of inactivity of adults may be involved. The impact of the detonation, if any, on adult lizards may be more clearly manifested in the spring of 1963, when definite evidence of differential survival as a function of distance from ground, ground zero may be obtained.

In species with non-overlapping generations, or in which only a few adults survive more than one year, adult mortality may be unimportant--provided that the production and survival of the next generation is unimpaired. Thus, the effects of nuclear detonations need to be evaluated in terms of the annual cycles of the animals involved. Immense adult mortality at one time of year may be critical; a few months later inconsequential.

Some evidence of the effects of the detonation on survival of juvenile lizards was obtained. During August, juvenile lizards (especially *Uta stansburiana*) were trapped as close as 2800 ft, and also at 3800 and 9000 ft from ground zero. The juveniles were evidently hatched after the test, but before post-test sampling was begun. Apparently, neither the eggs nor the hatching of eggs was seriously influenced by deposition of up to 6" to 12" of dirt. However, between August and November, differential mortality occurred among the young *Uta*. Mortality at 9000 ft was slight, greater at 3800 ft, and evidently almost complete at 2800 ft. The mortality was well correlated with the relative degree of habitat disruption, and probably was due more to destruction of cover than to gamma irradiation.

Northeast of ground zero, cumulative free-air gamma dosages for 5 weeks following the test ranged from at least 5000 r (at about 3000 ft from ground zero) to only 300-400 r at 8000 to 10,000 ft from ground zero. In areas where free-air doses and doses registered 2" underground were compared to tissue doses, the tissue doses and the underground doses were of similar magnitude and only about 10-15% of the free-air dose. The tissue doses received at 4500 ft (<550 r) are considered sublethal. Potential delayed effects are unknown.

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INFLUENCE OF A CRATERING DEVICE ON CLOSE-IN POPULATIONS OF LIZARDS

1. INTRODUCTION

In May of 1962, The Atomic Energy Commission made plans to detonate a 100 kiloton device on July 6, 1962, 650 ft underground at the north end of Yucca Flat. This operation was called Sedan.

During past test series at the Nevada Test Site, there has been considerable off-site work pertaining to the assimilation of fallout radioisotopes by mammals. But there have never been any quantitative studies of the local influences of nuclear detonations on natural populations of vertebrates. As a part of a broader cooperative investigation of the ecological influences of the projected underground detonation, a study of lizard populations existing within 10,000 feet of ground zero was designed.

When a 100 kiloton device is buried 650 feet below ground level, the most important events, from the standpoint of vertebrates occupying close-in areas, are probably the deposition of dirt and debris from the crater and the emanation of gamma radiation from this debris. Hence, the following questions were raised. Is mortality increased in lizard populations existing in areas close to an underground nuclear detonation? If so, how is the severity of the effect related to proximity to ground zero? Is it possible to differentiate between mortality owing to irradiation and that due to deposition of ejected debris? What are the approximate gross gamma dosages experienced by lizards occupying close-in areas, and how are tissue doses related to free-air doses? Are there, following an underground detonation, redistributions of lizards within close-in areas because of disruption of habitat?

2. PROCEDURE

2.1 Establishment of study areas and sampling procedures

The area to the northeast of the projected ground zero was the least modified by previous tests, and this area was selected for examination of lizard populations. On June 14, 1962, Line 16A (58° grid azimuth) was surveyed and marked at 500 ft intervals by Holmes and Narver, Inc. This line extended from ground zero (4317 ft above sea level) to 10,000 ft (4496 ft above sea level). Seven study plots were established and marked: 750 to 1000 ft, 1500-2000 ft, 2500-3000 ft, 3500-4000 ft, 4500-5000 ft, 5500-6000 ft, and 8500-9000 ft. These plots extended at right angles 750 ft on each side of the line and were, except for the first, 750,000 sq ft (17.2 acres) in area. The most proximal plot was 375,000 sq ft.

Each of the 7 study plots was examined three times, at approximately weekly intervals, between June 16 and July 5. From two to four men moved through an area and captured lizards by hand or noosing. Lizards were permanently marked by toe-clipping (at least one toe was removed from each foot), and temporarily marked with fast-drying paint. The colored mark prevented loss of time in attempting to capture a marked animal twice on the same day. The location of each lizard captured or recaptured was recorded on a map and the animals were released at that point.

Initially, it was planned to estimate the pre-test density of the more common species of lizards by the triple-catch method[1], using simple maximum-likelihood equations for population size estimates and the variances of these estimates. However, so few marked animals were re-

captured that population sizes were estimated by the proportional index[1, 2].

Another line (Line 12A) was surveyed by Holmes and Narver, Inc., on June 15, extending 12,000 ft north-northeast from ground zero (grid azimuth of 26°). This line was marked off similarly to Line 16A, but only an area 1000 ft on a side, centered on the line between 3500 and 4500 ft from ground zero, is pertinent to this study. In this area small glass microdosimeters were implanted in 33 lizards on July 4 and 5.

Between 3530 and 3800 ft on Line 16A, a 10x10 grid of 100 buried can traps was established on June 21. The traps were 30 feet apart and the grid was centered on the surveyed line. A similar grid was set up between 8730 and 9000 ft on June 23. The cans were 6.9" deep and 6.3" in diameter. All traps were covered with a square foot of masonite mounted on one inch legs at each corner. Except for June 27, when a small device was exploded on Yucca Flat, traps of both grids were examined daily between June 22 and July 5. These grids sampled areas somewhat more than 72,900 sq ft in extent. The data from these traps were to be used as a check on the estimates of abundance derived for the larger areas. Lizards captured were removed, marked and released as described above. Traps were sealed on the afternoon of July 5.

In order to evaluate the amount of overburden deposited on Line 16A, elevations above mean sea level were surveyed by Holmes and Narver, Inc., at 6 points along the line on July 4. These stations were at 750, 1000, 1500, 2000, 2250, and 2500 ft from ground zero. In October, elevations were surveyed along the line at 1500, 2000, 2250, and 2500 ft from ground

zero. The deposition at 750 and 1000 ft was estimated from aerial photographs.

After the test, radiation intensities prevented any systematic work in most of the study areas for over a month. However, on July 30, 24 days after the shot, investigations were resumed in the more distant areas. The devastation within 3000 ft of ground zero was so great that no detailed investigation of this area was carried out. However, the areas between 4500-5000, 5500-6000, and 8500-9000 ft were examined 3 times, at weekly intervals, between August 11 and August 29. The 3500-4000 ft area was examined once, on August 15. In the fall, these same areas were inspected twice between November 5 and November 13.

The grid of traps at 9000 was undamaged and was reactivated on July 30. The grid at 3800 ft was buried and a new grid was established on August 15. Additionally, a group of 50 traps was installed at 2800 ft on August 16. All of these traps were examined periodically until September 1, and then closed. In the fall, these three grids were reactivated on October 28 and examined daily until November 13.

2.2 Dosimetry

Three types of dosimeters were used. The first of these was a combination glass and chemical dosimeter with a range of 10 to 10 million roentgens prepared by Edgerton, Germeshausen and Grier of Santa Barbara, California. These cylindrical dosimeters were encased by a lead shield 20 mm thick and were 2 1/2" long and 3/4" in diameter. Twenty six of these dosimeters were pre-located on Line 16A, two at each of 13 stations. The stations were located 1500 ft from ground zero, and at 500 ft intervals thereafter to 5000 ft; then at 1000 ft intervals to

10,000 ft. Both dosimeters were taped to a steel fence post, one 2" from the ground; the other at 36". Both dosimeters were mounted on the ground zero side of the post. Twenty of these dosimeters were recovered on August 10, 35 days after the detonation. The others were destroyed or blown away by the blast. For example, a dosimeter originally mounted at 36" 3000 ft from ground zero was later found at 3500 ft. One dosimeter recovered was not interpretable. On Line 12A two combination dosimeters were pre-located, both 2" underground. One was at 3500 ft from ground zero, the other at 4000 ft, and two at 4500 ft. These were recovered on August 14.

The second type of dosimeter was made up of a film packet and a silica gel desiccant in a polyethylene bag wrapped in aluminum foil. These dosimeters were also prepared by E. G. & G. and had a range of 150 mr to 1000 r. Each packet was 4" x 3" x 2 1/2". Two were pre-located on Line 16A, one at 3000 ft, the other 8000 ft (at 36"). The former was not recovered; the latter was picked up on July 13, 7 days after the detonation. Four of these packets were set out on Line 12A, buried 2" underground. Two were located at 3500 ft and two at 4000 ft. Three of these 4 dosimeters were recovered on July 28. A single film packet was mounted on a stake at 36" at 4000 ft from ground zero.

After recovery, all of the E. G. & G. dosimeters were shipped to Santa Barbara and read under the direction of Chapman Leek. Readings were returned to our laboratory as total roentgens of gross gamma exposure.

The third type of dosimeter was a Bausch & Lomb low-z glass microdosimeter. These dosimeters are cylinders of silver-activated phosphate

glass, 1 mm in diameter and 6 mm long. They are capable of registering 10 to 10,000 r. They are also small enough to be implanted in small vertebrates, and are potentially useful in assessing tissue dosages as opposed to free-air dose. Because they are unshielded and because there is a 5 to 10-fold overresponse to gamma radiations in the energy range from 20 to 80 kev, these rods give only rough approximations of true dose[3]. They do, at least, establish a "ceiling" to the amount of gross gamma irradiation experienced by an animal.

Bausch & Lomb microdosimeters were implanted in lizards inhabiting the study area on Line 12A on July 4 and 5. On July 4, 11 *Cnemidophorus tigris*, 6 *Crotaphytus wislizeni*, and 1 *Sceloporus magister* were captured, and two microdosimeters were implanted beneath the skin of the dorsum of each - one in the region of the neck, and the other in the lumbar region. Implantation was by means of a specially modified hypodermic needle. A slender steel rod was attached to the plunger and adjusted in length so that when the plunger was depressed the tip of the rod just reached the aperture of the needle. The microdosimeter was placed inside the tip of the needle and shaken down. The needle was then inserted carefully beneath the skin of the lizard and the plunger depressed, forcing the microdosimeter into place. The small wound was sealed with collodion and the animals marked and released at point of capture. On July 5, dosimeters were implanted in 14 *Cnemidophorus* and 1 *Crotaphytus* in the same area. One of the *Cnemidophorus* received only one dosimeter. There were, then, in an area 1000 ft square on Line 12A (3500-4500) 33 marked lizards. All but one had 2 dosimeters inserted beneath the skin.

Twelve attempts to recover some of these lizards (by shooting) were made between July 28 and September 1 (about 22 man-hours). Two marked lizards were shot on July 28 and three microdosimeters recovered. One of these lizards had received but one dosimeter originally. On August 11, to supplement the recovery effort, 50 can traps were established along Line 12A between 3500 ft and 6000 ft from ground zero. These traps were inspected periodically until September 1. In the fall, these traps were examined daily between October 28 and November 13.

The three microdosimeters recovered were read on a Bausch & Lomb microdosimeter reader (Catalog No. 33-66-02).

2.3 Sampling of Arthropods

In addition to lizards, the buried cans trapped a variety of arthropods. Records of captures of the more abundant species were kept for the trap grids at 3800 ft and 9000 ft on Line 16A for a two-week interval between June 22 and July 5, and a two-week interval between August 18 and 31. Records were kept for the 50 traps at 2800 ft between August 22 and 31.

3. RESULTS

3.1 Physiography and Vegetation

Yucca Flat is a desert basin about 15 miles long and 10 miles wide, located in the northern portion of the Nevada Test Site. Floristically it is a part of a broad transition between the Mojave Desert to the south and the Great Basin to the north. Area 10 is in the northernmost part of Yucca Flat and was the site of the Sedan test. This area has been used for underground testing in the past, and in places much of the native vegetation has been destroyed and replaced by *Salsola kali*,

and Mentzelia albicaulis (Fig. 1). In the vicinity of the prospective ground zero these plants were dominants. However, to the northeast of ground zero (beyond about 3000 ft) the vegetation was relatively undisturbed and composed predominantly of shrubs. Both Grayia spinosa and Coleogyne ramosissima are abundant, but on Line 16A the latter is more abundant. A mixture of Grayia and Coleogyne occurs along Line 16A between about 3000 and 7000 ft (Fig. 2), but at greater distances from ground zero Coleogyne is by far the most abundant shrub (Fig. 3).

3.2 Sampling of Lizards Prior to the Test

In the 7 plots on Line 16A examined prior to the test, 6 species of lizards were observed or captured. These were the whiptailed lizard (Cnemidophorus tigris), the leopard lizard (Crotaphytus wislizeni), the side-blotched uta (Uta stansburiana), the horned lizard (Phrynosoma platyrhinos), the banded gecko (Coleonyx variegatus), and the gridiron-tailed lizard (Callisaurus draconoides). The desert spiny lizard (Sceloporus magister) and the yucca night lizard (Xantusia vigilis) may have occurred, but were not recorded. Only data pertaining to Cnemidophorus, Crotaphytus, Uta, and Phrynosoma were taken.

A rough index of the relative abundance of these 4 species is afforded by Table 1.

The only species captured often enough to justify more detailed analysis is Cnemidophorus tigris. The density of this species is fairly uniform in the four areas examined between 2500 and 6000 ft on Line 16A. In fact, data from the area examined on Line 12A (also a Grayia-Coleogyne association) are similar to these (Table 2).

The data pertaining to Cnemidophorus on Line 16A have been treated in a conventional capture-recapture analysis (Table 3). These figures reflect the manual collections in the 7 large plots, as well as records from the 100-trap grids at 3800 ft and 9000 ft. Because the trap grids were parts of larger areas assessed by hand-collecting, it was necessary to treat data derived by each means of collection independently of the other. In other words, if an animal were first captured by hand in the 3500-4000 ft or the 8500-9000 ft plot, and later trapped, it was assumed (in treating the trap data) that this was an initial capture. Similarly, if an animal were first marked following capture in a trap, and later captured by hand, the latter event was considered an original capture in analyzing manual collection data. Table 3 shows conventional capture-recapture data, the population estimate (N), the estimated variance of N, the minimum population size (as indicated by all animals registered during the sampling), and the estimated standard deviation of N. All estimates have been calculated as suggested by Bailey.[1]

3.3 Gross Effects of the Detonation

On 10 A.M., on July 6, 1962, the device (100 kilotons) was detonated 650 ft below the ground in Area 10 of Yucca Flat. It is estimated that about 7 million cubic yards of alluvium were displaced.[4] The resulting crater was about 1280 ft in diameter and almost 400 ft deep from the top of the crater lip (Fig. 4). The average depth from original ground level was 320 ft. The lip itself was as much as 75 ft high in places but only about 40-50 ft high over most of its circumference. At 1000 ft from ground zero as much as 37 ft of dirt was deposited in places, but usually the deposition at this distance was around 20 ft. At

2500 ft (Fig. 5) deposition was ordinarily around 3 to 6 in but depths of up to 1 ft were recorded by Holmes and Narver, Inc.[4] Depositions (as determined by pre- and post-test surveys) of overburden at 35 points between 750 and 2500 ft from ground zero are shown in Appendix A, and the overburden on Line 16A is shown in Table 4. The deposition of dirt on Line 16A was much less than the average for points closer than 1500 ft, slightly more at 2000 ft and 2500 ft (Appendix A). Thus Line 16A received less than the average dirt fall.

A general description of the extent of the overburden at greater distances is given by Martin.[5] Martin also describes the appearance and extent of three zones surrounding the crater, particularly in terms of effects on vegetation. In Zone A, which extended to about 2000 ft on Line 16A, all of the vegetation was destroyed by the blast and the deposition of dirt. Zone B extended from 2000 ft to 5000 ft on Line 16A, and in this belt the vetetation was damaged but not entirely destroyed (Fig. 6). In Zone C, extending beyond about 5000 ft the vegetation showed no visible damage but was heavily blanketed with radioactive dust.

3.4 Sampling of Lizards After the Test

The devastation of the study plots closer to ground zero than 3000 ft (Fig. 5) was such that no sampling was conducted in these areas other than by a grid of 50 traps established between 2650 and 2800 ft on August 16. Between this date and September 1, 23 juvenile *Uta* and 1 juvenile *Crotaphytus* were captured. Between October 28 and November 13, no lizards of any kind were taken. The areas farther from ground zero were sampled by manual collecting and with traps, as

described earlier. The results of the post-test sampling on Line 16A are given in Table 5. The data derived from the trap grids afford estimates (Table 6) of the post-test density of juvenile Uta in areas 3800 and 9000 ft from ground zero (see DeLury[6]).

Between July 28 and September 1, and again in the fall, an effort was made to recover microdosimeters from the 33 lizards captured and released on Line 12A just prior to the test. It will be recalled that on July 4 and 5, three men (in 24 man-hours) captured 33 adult lizards (25 of them Cnemidophorus). However, in the course of 22 man-hours spent in this area between July 28 and September 1, only 2 adult Cnemidophorus were shot and one other observed. Also observed were about a dozen juvenile Uta, 2 juvenile Crotaphytus and one juvenile Phrynosoma. The 50 can traps established along Line 12A (as far out as 6000 ft) captured 3 juvenile Crotaphytus and 73 juvenile Uta in 175 daylight trap-hours between August 16 and September 1. Between October 28 and November 13, these traps captured 38 juvenile Uta in 160 daylight trap-hours.

3.5 Dosimetry

Free-air doses on Lines 12A and 16A, doses 2" below ground on Line 12A, and approximate tissue doses to two lizards collected on July 28 are recorded in Table 7.

3.6 Sampling of Arthropods

Captures of arthropods in can traps prior to the test and after the test are shown in Table 8.

4. DISCUSSION

4.1 Pre-test Densities of Lizards

The foregoing data afford estimates of the relative abundance of lizard species before and after the test, if one accepts the frequency of capture per unit of effort as a reliable index of total numbers. As will be seen, this assumption may be invalid under the particular conditions of the Sedan operation.

However, the following conclusions are drawn from the data in Tables 1 and 2. In shrubby areas, as existed along Line 16A between 3000 and 6000 ft,and even in areas supporting predominantly _Salsola_ with a few interspersed shrubs of _Grayia_ (_e.g._, 2500-3000 ft on Line 16A), the abundance of _Cnemidophorus tigris_ was uniform (Fig. 2). These lizards were less abundant in disturbed areas closer to the prospective ground zero and at 9000 ft in an area grown predominantly with _Coleogyne_ (Fig. 3). Leopard lizards (_Crotaphytus wislizeni_) were uniformly distributed along Line 16A except in the highly disturbed areas close to ground zero (Fig. 1). _Uta stansburiana_ was relatively most abundant close to ground zero and apparently less numerous at greater distances. This last conclusion is tentative because _Uta_ is not particularly conspicuous, and differences in the vegetation might have influenced the ease with which this species was observed and captured. Horned lizards were rarely captured in any area and this species will not be treated in the following discussion.

The decline in apparent numbers of the first three of the above four species after the test is evident from Tables 1 and 5.

Estimates of absolute abundance of lizards before and after the test would be preferable to relative indices of numbers. However, only the information pertaining to Cnemidophorus tigris before the detonation hold any promise in this regard (Table 3). These data are disappointing because of the large variances of the estimates. The large variances stem from the low recapture success, which indicates that the 17.2 acre plots examined were too large for the time and personnel available.

There is reasonable consistency in the four plots where more than 30 Cnemidophorus were registered during the pre-test sampling (Table 3). The population estimates are 100, 130, 87, and 95 adult lizards per 17.2 acres, and imply about 6 adult whiptailed lizards per acre. At first glance this density estimate is not supported by the data from the traps at 3800 feet.

Observe that in this trap grid (72,900 sq ft, or 1.7 acres), 29 different lizards were registered during the sampling, and the population estimate for the area was 38 (29-55). This implies about 22 adult Cnemidophorus per acre (see above). Similarly, at 9000 ft the population estimate for the 8500-9000 ft plot (17.2 acres) is 55 (3.2/acre), while the estimate for the traps grid between 8730 and 9000 ft is 10 (5.9/acre).

However, it must be recognized that the areas sampled were actually greater than 17.2 and 1.7 acres, because of movements of lizards. Fifty-seven movements of adult Cnemidophorus recorded during the pre-test sampling ranged from 10 to 1860 ft. The median of this distribution is about 135 ft. If the areas sampled, both

manually and by traps, are increased 135 ft on a side, to compensate for normal movements of lizards, the resulting areas and adjusted density estimates are as shown in Table 9. As may be seen, the disparity between trap-based density estimates and those based on manual catch data are not now as great.

However, it is concluded that the hand capture-recapture estimates for the large plots are probably too low. It is also likely that the upper confidence limits of these estimates (Table 9) are too high, in view of the independently derived density estimates based on trapping data. In summary, it is concluded that in the shrub belt (*Grayia-Coleogyne* mixture) lying to the north of ground zero, the pre-test density of adult *Cnemidophorus tigris* was no less than 5, nor more than 10 per acre. Seven per acre is taken as the best estimate.

If this datum is accepted, some further extrapolations are possible. Assume that at a density of 7 *Cnemidophorus* per acre, 1.6 lizards will be observed and/or captured per man-hour (see Table 1). Then the capture-recapture estimates for the 750-1000 and 1500-2000 ft plots are possibly too low, implying densities of 0.7 and 0.9 lizards/acre, respectively, in these areas; while the catch per unit effort suggests densities of about 2 and 3 per acre respectively. Alternatively, the conspicuousness of whiptailed lizards may have been different in the close-in areas.

If one assumes that *Crotaphytus wislizeni* is encountered with the same frequency as *Cnemidophorus tigris*, one may convert the leopard lizards/man-hour figures in Table 1 to estimates of absolute numbers. In the plots on Line 16A between 1500 and 9000 ft the mean number of

leopard lizards observed and/or captured per man-hour was 0.24. This datum may be converted, in accordance with the assumption stated above, to 1.0 adult Crotaphytus wislizeni per acre before the test. This is a crude estimate, so 2.0 per acre might be taken as an upper limit.

4.2 Post-test Densities of Adult Lizards

After the test the deposition of overburden on Line 16A was so great out to 2000 ft that it was assumed that no lizards survived closer in. Between 2000 and 3000 ft, no adult lizards were observed or trapped in August or in the fall. In fact, after the test no adult lizards were observed closer to ground zero than 5500 ft. However, beyond 8000 ft, in areas where there was no damage to the habitat and where gross gamma dosages were certainly sublethal, adult lizards were rarely observed, either in August or in the fall (Table 5). The low apparent incidence of adult lizards after the test is at least partly owing to seasonal inactivity. This view is supported by some of the long-term lizard trapping data accumulated by investigators of Brigham Young University.[7]

It should be borne in mind that in species with non-overlapping generations (or in which only a few adults survive more than one year), extraneously induced adult mortality may be unimportant. If the production and survival of the next generation is unimpaired by a nuclear detonation, massive mortality among adults is inconsequential. The critical stages would then be the eggs or immatures.

4.3 Post-test Densities of Juvenile Lizards

In the three species considered above, the hatching of young occurred following the test and prior to the resumption of sampling in August. These young individuals were not easily captured by hand

but were taken in traps, on Line 16A and on Line 12A. The hatching of lizard eggs did not seem to have been affected by the test, at least beyond 2000 ft. Of the juveniles captured, almost all were _Uta stansburiana_. In August, these tiny lizards were trapped in areas which, except for arthropods, appeared devoid of life (Table 5). From the data in Table 5, it may be observed that juvenile _Uta_ were captured readily in traps in August -- from as close as 2800 ft to 9000 ft from ground zero. Because there were only 50 traps at 2800 ft, the captures per hour (.15) are about the same as those which occurred at 3800 ft (.43) and 9000 ft (.26), where there were 100 traps. Estimates of the numbers of juvenile _Uta_ at 3800 and 9000 ft (per 72,900 + sq ft) are given in Table 6.

During August, only one juvenile _Uta_ was captured by hand, in the course of 107 man-hours of effort. These small lizards are inconspicuous and extremely difficult to capture by hand.

In October and November, the same type of sampling was repeated. At that time, no young _Uta_ were captured in cans at 2800 ft, and only 4 were captured in traps at 3800 ft. However, at 9000 ft, young _Uta_ were trapped with an efficiency (.21 per hour) only slightly reduced from that which occurred in August (.26 per hour). Also, although there were evidently far fewer young _Uta_ close-in, those present had grown and were more conspicuous. Two were captured in the plot at 3500-4000 ft, and in more distant plots a total of 33 young _Uta_ were captured (Table 5).

The trapping evidence indicates, then, an abundance of juvenile _Uta_ during August, from 2800 ft to 9000 ft on Line 16A. By the end of

October the abundance of these lizards was only slightly reduced at 9000 ft. However, at 3800 ft the number of young Uta was markedly reduced, and at 2800 ft these lizards were virtually extinct.

This pattern of mortality agrees well with the degree of general disruption of habitat and destruction of cover at different distances from ground zero. The close-in mortality is probably not attributable to radiation because the lizards affected were born some time after the detonation, when the intensity of the gamma field was reduced.

4.4 Dosimetry

Free-air cumulative gamma dosages for 5 weeks after the test on Line 16A ranged from at least 5000 r down to 300-400 r at 8000 to 10,000 ft (Table 7). On Line 12A, in the area examined between 3500 and 4500 ft, free-air doses were around 3000 r (Table 7). Doses at 2" from the ground did not differ significantly from those 3 ft above ground level. Doses 2" underground, as might be experienced by aestivating lizards, were only 400 or 500 r on Line 12A.

Tissue doses, as indicated by the three implanted microdosimeters recovered, indicated that 1) the position of implantation (at least on the dorsum) probably has no significant influence on the dose registered, *e.g.*, < 560 r and < 515 r in two from the same animal, and 2) cumulative gamma dose is a small fraction of cumulative free-air dose (*i.e.*, 500 or less *vs.* 3000 r). As pointed out above, the microdosimeter readings may be high--possibly by a factor of 2 or 3. The tissue doses are comparable to doses registered by underground dosimeters, a fact consistent with the habits of the animals.

4.5 Arthropods

The data pertaining to arthropods are impossible to interpret meaningfully (Table 8). Where before and after information is available (3800 and 9000 ft on Line 16A), there were no apparent changes in species composition except the appearance of large numbers of the tenebrionid beetle, *Pelecyphorus pantex*, at 2800 and 3800 ft after the test. These beetles apparently emerged from pupae some time after the test and before the resumption of post-test sampling. Captures of Jerusalem crickets (*Stenopelmatus fuscus*) were reduced drastically at 3800 ft but 25 were captured at 2800 ft during 10 days in late August. Other before and after differences have no consistent pattern and there is no way of appraising their significance, if any.

The only point of interest to emerge from the arthropod records is that at 2800 ft where 3 to 8 inches of dirt was deposited on July 6, arthropods were taken commonly in traps during the last 10 days of August and occasionally during October and November. Because the vegetation was completely destroyed in this area, it is interesting that the herbivorous arthropod species were able to persist.

Appendix A

DEPOSITION OF OVERBURDEN FOLLOWING THE SEDAN TEST

Distance from ground zero (ft)	Bearing from ground zero N 4° E	N 26° E	N 58° E	S 53° E	S 19° W	S 86° W	N 17° W
750	34.0*	27.0	16.2	46.1	19.7	9.7	94.2
1000	15.2	31.2	13.0	15.4	11.0	13.7	37.1
1500	12.3	3.2	2.3	1.3	8.6	1.9	3.5
2000	2.4	3.4	1.6	0.6	1.3	0.8	0.9
2500	0.1	0.4	0.6	0.5	0.0	0.2	0.3

* All values in ft

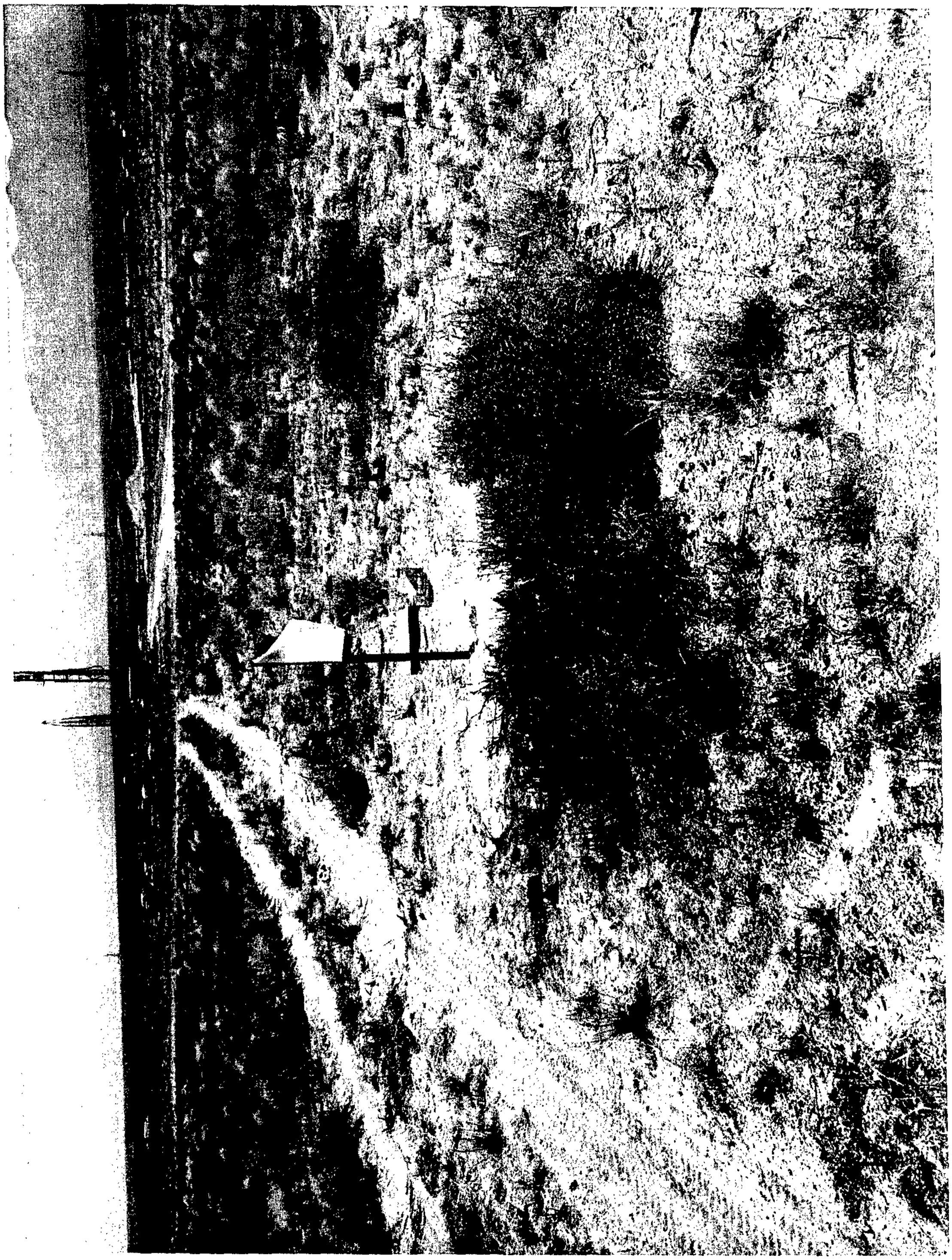

Figure 1 16A-1000-T 6/21/62

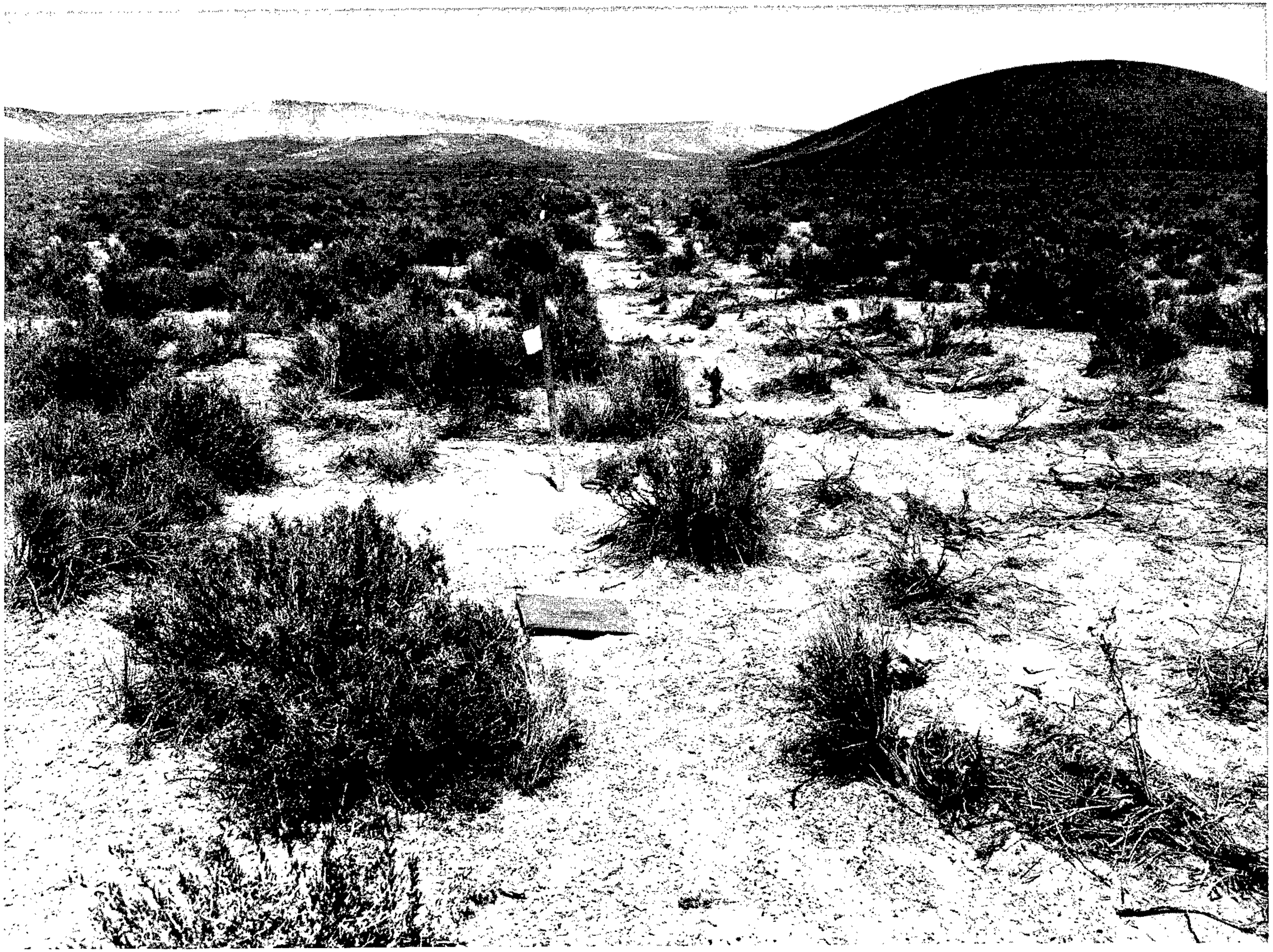

Figure 2 16A-5000-A 6/21/62

Figure 3 16A-9000-T 6/21/62

Figure 4

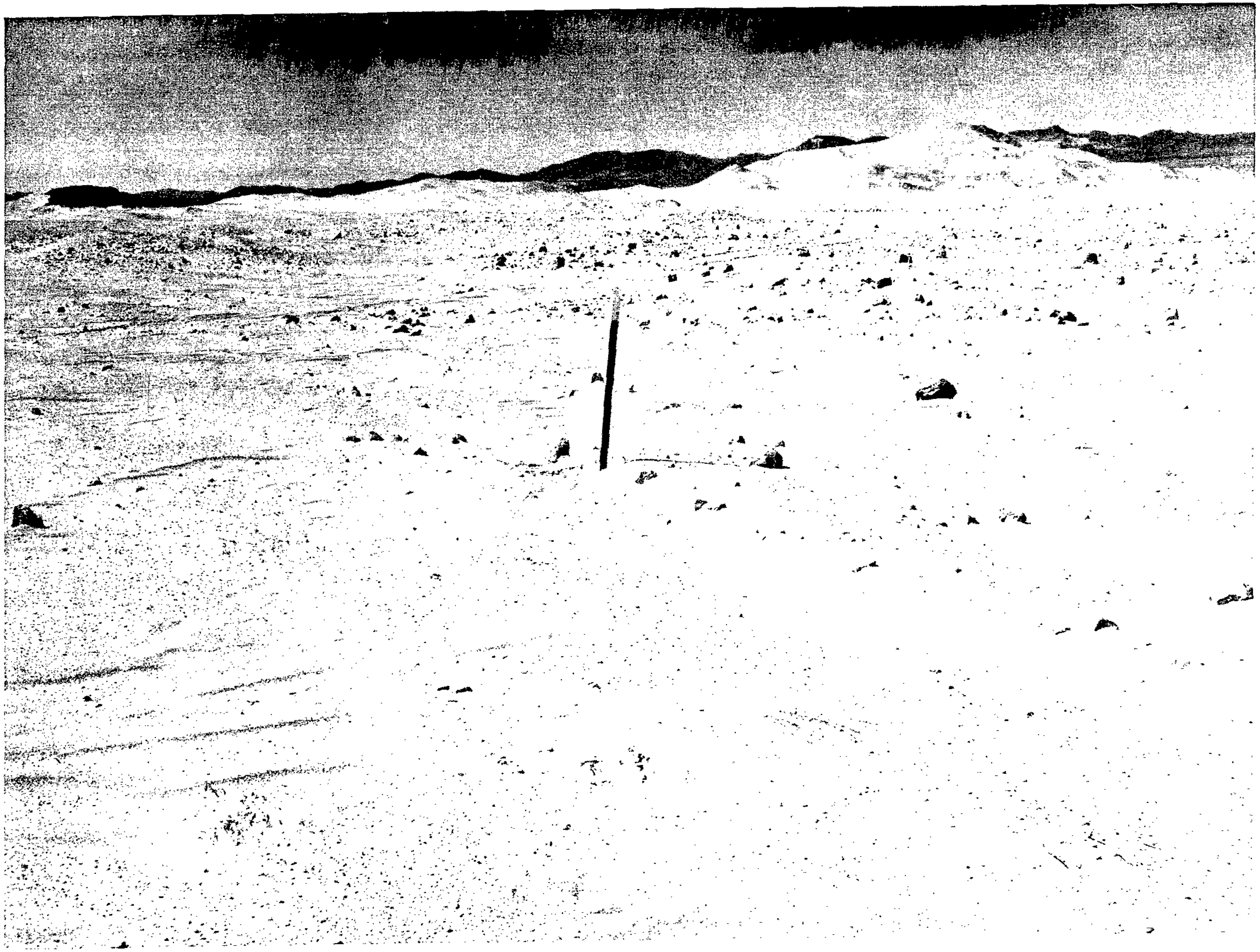

Figure 5   12A-2500-T   8/21/62

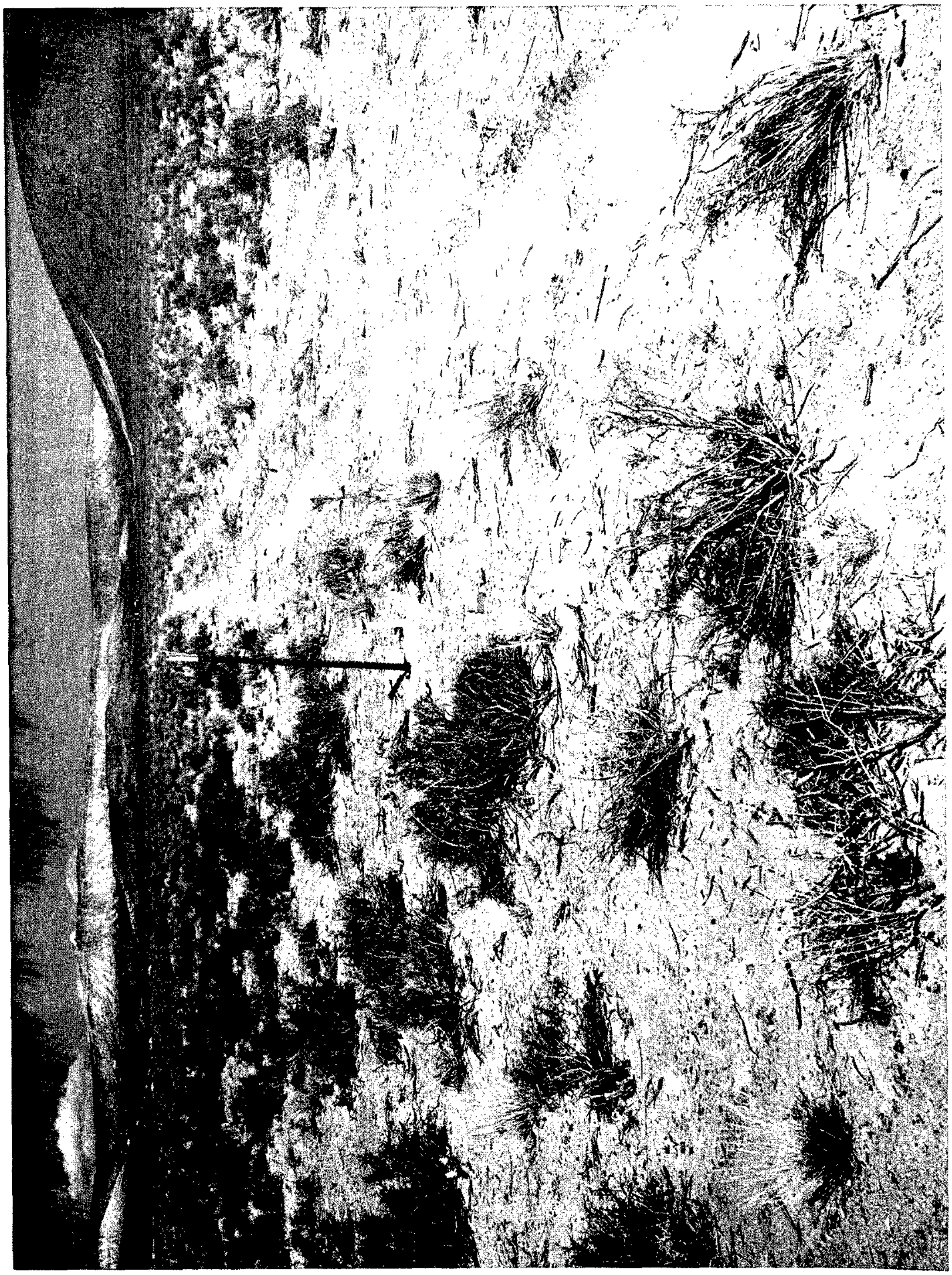

Figure 6 16A-5000-A 8/23/62

Table 1 - Adult lizards captured and observed per hour of effort on Line 16A between June 16 and July 5, 1962. The actual numbers are given in parentheses. The figures for the large plots are based on 3 censuses and represent all individuals registered, including recaptures

Study plot (ft from ground zero)	Daylight trap grid-hours or man-hours	Adult lizards captured or observed			
		Cnemidophorus tigris	*Crotaphytus wislizeni*	*Uta stansburiana*	*Phrynosoma platyrhinos*
750-1000	32.5	0.40 (13)	0.09 (3)	0.43 (14)	0.06 (2)
1500-2000	44.0	0.64 (28)	0.39 (17)	0.32 (14)	0.11 (5)
2500-3000	43.0	1.47 (63)	0.23 (10)	0.26 (11)	0.02 (1)
3500-4000	37.5	1.76 (66)	0.29 (11)	0.19 (7)	0.00 (0)
4500-5000	31.0	1.52 (47)	0.23 (7)	0.06 (2)	0.97 (3)
5500-6000	23.0	1.65 (38)	0.13 (3)	0.13 (3)	0.04 (1)
8500-9000	41.0	0.63 (26)	0.32 (13)	0.07 (3)	0.01 (0)
Traps					
3530-3800	196.0	0.25 (49)	0.005 (1)	0.06 (11)	0.00 (0)
8730-9000	164.0	0.08 (13)	0.01 (2)	0.04 (6)	0.01 (2)

Table 2 - Captures of _Cnemidophorus tigris_ per man-hour in selected areas on Lines 12A and 16A in Yucca Flat between June 16 and July 5, 1962. The figures for Line 16A are based on the sums of 3 censuses and include captures and recaptures. The figures for Line 12A are based on 2 censuses and there were no recaptures.

Area (ft from ground zero)	Man-hours	_Cnemidophorus_ captured	Captures/man-hour
Line 16A			
2500-3000	43.0	42	1.0
3500-4000	37.5	42	1.1
4500-5000	31.0	33	1.1
5500-6000	23.0	38	1.6
Line 12A			
3500-4500	24.0	25	1.0

Table 3 - Capture-recapture analysis of *Cnemidophorus* data pertaining to Line 16A, between June 16 and July 5, 1962. Minimum N is taken as the total lizards marked during all three censuses.

Area (ft from ground zero)	Total marked prior to last census (a)	Number captured at last census (n)	Recaptures at last census (r)	Estimate of N $a(n+1)/(r+1)$	Estimated variance of N $a^2n(n-r)/r^3$	s N	Minimum N
750-1000	4	4	1	10	192	13.9	7
1500-2000	11	7	3	22	125	11.2	15
2500-3000	20	19	3	100	4,504	67.1	36
3500-4000	26	14	2	130	14,196	119.2	38
3530-3800	25	11	7	38	80	8.9	29
4500-5000	20	12	2	87	6,000	77.5	30
5500-6000	19	19	3	95	4,065	63.8	35
8500-9000	11	9	1	55	8,712	93.3	19
8730-9000	8	4	3	10	9	3.0	9

Table 4 - Deposition of overburden on Line 16A by the Sedan detonation on July 6, 1962.

Distance from ground zero (ft)	Elevation (feet above mean sea level) as of July 4, 1962	Elevation as of October 23, 1962	Overburden deposited (feet)
750	4323.81	4340	16.2
1000	4328.04	4341	13.0
1500	4333.48	4335.8	2.3
2000	4339.56	4341.2	1.6
2250	4342.05	4342.5	0.5
2500	4344.63	4345.2	0.6

Table 5 - Captures and observations per hour of effort on Line 16A between July 30 and September 1 (above), and October 28 and November 13, (below). The actual numbers are given in parentheses. Data do not include two adult Phryhosoma captured in traps at 9000 ft from ground zero in August

Area (ft from ground zero)	Daylight trap grid-hours or man-hours	Cnemidophorus Adult	Cnemidophorus Juvenile	Crotaphytus Adult	Crotaphytus Juvenile	Uta Adult	Uta Juvenile
2650-2800	168	0	0	0	.01 (2)	0	.15 (26)
(50 traps)	160	0	0	0	0	0	0
3500-4000	11	0	0	0	0	0	0
	7	0	0	0	0	0	.29 (2)
3530-3800	224	0	0	0	.02 (5)	0	.43 (97)
(100 traps)	150	0	0	0	0	0	.03 (4)
4500-5000	27	0	0	0	0	0	0
	8	0	0	0	0	0	1.0 (8)
5500-6000	27	.07 (2)	.11 (3)	0	0	0	0
	10	0	0	0	0	0	1.5 (15)
8500-9000	42	.02 (1)	0	.05 (2)	.02 (1)	0	.02 (1)
	10	0	0	0	0	0	1.0 (10)
8730-9000	476	.02*(10)	.006 (3)	0	.006 (3)	.004(2)	.26 (123)
(100 traps)	160	0	0	0	0	0	.21 (34)

* One individual 6 times and 4 other individuals

Table 6 - Capture-recapture estimates of abundance of juvenile *Uta* in two plots (72,900 sq ft) on Line 16A in Yucca Flat during August 1962. X_t is the number of marked individuals at risk in the population at time of sample t, n_t is the total size of the sample at time t, and x_t is the number of marked individuals captured at time t.

Area (ft from ground zero)	Census interval (t)	X_t	n_t	x_t	$x_t X_t$	$n_t X_t^2$	Population estimate $\frac{\Sigma n_t X_t^2}{\Sigma x_t X_t}$
3800	1	24	49	8	192	28,224	
	2	65	35	16	1,040	147,875	
	3	84	26	13	1,092	183,456	
				Σ	2,324	359,555	158
9000	1	43	36	9	387	66,564	
	2	70	24	8	560	117,600	
				Σ	947	184,164	194

Table 7 - Cumulative gross gamma dosages recorded by dosimeters pre-located on Lines 12A and 16A before the Sedan test. Film badges are indicated by (fb), glass microdosimeters by (m). All other dosimeters are lead-shielded combination glass and chemical dosimeters. Film badge data are ± 25%, combination dosimeter data are ± 15%.

	LINE 16A			LINE 12A		
Location of dosimeter (ft from ground zero)	Disposition & type of dosimeter	Days of exposure	Cumulative gross gamma dosage (r)	Disposition & type of dosimeter	Days of exposure	Cumulative gross gamma dosage (r)
1500	2"	35	3200			
2500	2"	"	4900			
	36"	"	8800			
3000	2"	"	5100			
3500	2"	"	4200	2"	39	3200
	36"	"	4300	36"	"	3300
				2" below ground	22	400
				"(fb)	"	400
				"(fb)	"	>1500
4000	36"	"	2800	2"	39	3400
				36"	"	3200
				36"(fb)	"	>1500
				2" below ground (fb)	22	500
4500	2"	"	330(?)	2"	39	2600
	36"	"	3400	36"	"	3000
				in lizard(m)	22	<560
				"	"	<515
				"	"	<465
5000	2"	"	1750			
	36"	"	2000			
6000	2"	"	1200			
	36"	"	360			
7000	2"	"	890			
	36"	"	870			
8000	2"	"	370			
	36"	"	300			
	36"(fb)	7	250			
9000	36"	35	380			
10,000	2"	"	420			
	36"	"	410			

Table 8 - Captures of arthropods in can traps on Line 16A in Yucca Flat before and after the Sedan test

Arthropod species	3800 ft (100 traps) June 22-July 5 (14 days)	3800 ft (100 traps) August 18-31 (14 days)	9000 ft (100 traps) June 24-July 5 (12 days)	9000 ft (100 traps) August 18-31 (12 days)	2800 ft (50 traps) August 22-31 (10 days)
Solpugid (*Eremorhax*)	28	20	11	10	4
Vejovis confusus	28	106	19	22	30
Hadrurus hirsutus	11	43	5	14	6
Arenivaga apacha	2	16	2	4	7
Stenopelmatus fuscus	76	19	3	0	25
Ceuthophilus sp.	16	6	5	6	2
Trogloderus costatus	20	91	6	1	91
Eleodes armata	40	20	18	9	10
E. hispilabris	11	31	8	8	6
Pelecyphorus pantex	0	532	0	6	91

Table 9 - Estimated densities of *Cnemidophorus tigris* in plots on Line 16A during June, 1962. Areas of plots are adjusted to compensate for movements of lizards.

Area (ft from ground zero)	Estimated Population	95% confidence limits (upper limit is + 1.96 s_N, lower limit is -1.96 s_N or total lizards registered, whichever is greater)	Adjusted area sampled (acres)	Estimated density (lizards/acre)
2500-3000	100	36-232	23.8	4.2
3500-4000	130	38-364	"	5.5
3530-3800 (traps)	38	29-55	3.7	9.7
4500-5000	87	30-239	23.8	3.7
5500-6000	95	35-220	"	4.0
8500-9000	55	19-238	"	2.3
8730-9000 (traps)	10	9-16	3.7	2.7

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SC	Sandia Corporation, Sandia Base, Albuquerque, New Mexico
USC&GS	U. S. Coast and Geodetic Survey, San Francisco, California
LRL	Lawrence Radiation Laboratory, Livermore, California
LRL-N	Lawrence Radiation Laboratory, Mercury, Nevada
Boeing	The Boeing Company, Aero-Space Division, Seattle 24, Washington
USGS	Geological Survey, Denver, Colorado, Menlo Park, Calif., and Vicksburg, Mississippi
WES	USA Corps of Engineers, Waterways Experiment Station, Jackson, Mississippi
EGG	Edgerton, Germeshausen, and Grier, Inc., Las Vegas, Nevada, Santa Barbara, Calif., and Boston, Massachusetts
BYU	Brigham Young University, Provo, Utah
UCLA	UCLA School of Medicine, Dept. of Biophysics and Nuclear Medicine, Los Angeles, Calif.
NRDL	Naval Radiological Defense Laboratory, Hunters Point, Calif.
USPHS	U. S. Public Health Service, Las Vegas, Nevada
USWB	U. S. Weather Bureau, Las Vegas, Nevada
USBM	U. S. Bureau of Mines, Washington, D. C.
FAA	Federal Aviation Agency, Salt Lake City, Utah
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